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Where is the Metallicity Ceiling to Form Carbon Stars? – A Scarcity of Carbon Stars in the Inner Disk of M31

Martha L. Boyer,[1] L. Girardi,[2] P. Marigo,[3] B. F. Williams,[4] B. Aringer,[5] W. Nowotny,[5] P. Rosenfield,[3,4] C. E. Dorman,[6] P. Guhathakurta,[6] J. J. Dalcanton,[4] J. L. Melbourne,[7] K. A. G. Olsen,[8] and D. R. Weisz[6]

[1]*Observational Cosmology Lab, NASA Goddard Space Flight Center, Greenbelt MD,USA*

[2]*INAF – Osservatorio Astronomico di Padova, Italy*

[3]*Dept. of Physics and Astronomy G. Galilei, University of Padova, Italy*

[4]*Dept. of Astronomy, University of Washington, Seattle WA, USA*

[5]*Dept. of Astrophysics, University of Vienna, Austria*

[6]*University of California Observatories/Lick Obervatory, Santa Cruz CA, USA*

[7]*Caltech Optical Observatories, Pasadena CA, USA*

[8]*National Optical Astronomy Observatories, Tucson AZ, USA*

Abstract. We have used a novel technique involving near-infrared colors from the Hubble Space Telescope to distinguish C stars from M stars in a field in M31. The resulting C/M ratio is much lower than other estimates in M31.

Carbon stars are far more efficient at producing dust than O-rich (M-type) Asymptotic Giant Branch (AGB) stars (e.g. Matsuura et al. 2009; Srinivasan et al. 2009), and may be the dominant stellar dust source in galaxies (e.g. Boyer et al. 2012; Zhukovska & Henning 2013). They are also responsible for a major share of galaxy luminosity (e.g. Melbourne & Boyer 2013) and contribute significantly to the chemical enrichment of the interstellar medium (e.g. Karakas & Lattanzio 2007; Marigo 2001; Ventura et al. 2001). Because of their vital role in galaxy evolution and in interpreting the observations of unresolved galaxies, it is important to devise a method to efficiently identify C stars in distant systems that will become resolvable with new large telescopes.

In Boyer et al. (2013), we use medium-band near-infrared (NIR) Hubble Space Telescope WFC3 photometry with model NIR spectra of Asymptotic Giant Branch (AGB) stars to develop a new tool for efficiently distinguishing carbon-rich (C-type) AGB stars from oxygen-rich (M-type) AGB stars in galaxies at the edge of and outside the Local Group (Figure 1). We test this technique in a $2.'3 \times 2.'1$ field of the inner disk of M31, 2 kpc from the center, where several C star candidates were detected via their JHK colors (Davidge et al. 2005). We detect only 1 candidate C star (plus up to 6 additional, less certain C stars candidates), resulting in an extremely low ratio of C to M stars ($C/M = 3.3^{+20}_{-0.1} \times 10^{-4}$) that is ~2 orders of magnitude lower than other C/M estimates in M31 (Brewer et al. 1995).

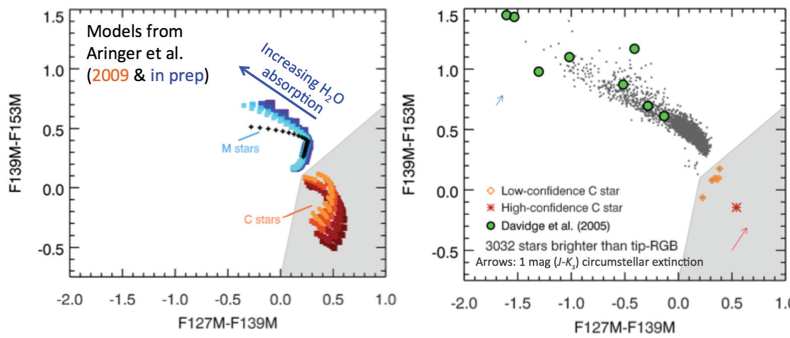

Figure 1. *Left:* The F139M-F153M and F127M-F139M color combination efficiently separates C and M type AGB stars with little to no overlap. In addition, M type stars follow a sequence of increasing H_2O absorption, and thus temperature. *Right:* The same for the observed region of M31. Only one candidate C star is detected with high confidence. The candidate C stars from Davidge et al. (2005) are instead late-type M stars with deep H_2O absorption. H_2O absorption causes red JHK colors; caution is required when using standard NIR filters to identify C stars.

The low C/M ratio is likely due to the high metallicity in this region which impedes stars from achieving C/O > 1 in their atmospheres (Marigo et al. 2013). Previous C star identifications in this region using JHK colors are likely misidentified M stars with deep water absorption near 1.4 μm. These observations provide stringent constraints to evolutionary models of metal-rich AGB stars and point to a metallicity threshold above which M stars are unable to make the transition to C stars, dramatically affecting AGB mass loss and dust production and, consequently, the observed global properties of metal-rich galaxies. The metallicity of our field suggests that the ceiling for C stars falls in the range $-0.1 < [M/H] < +0.1$.

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